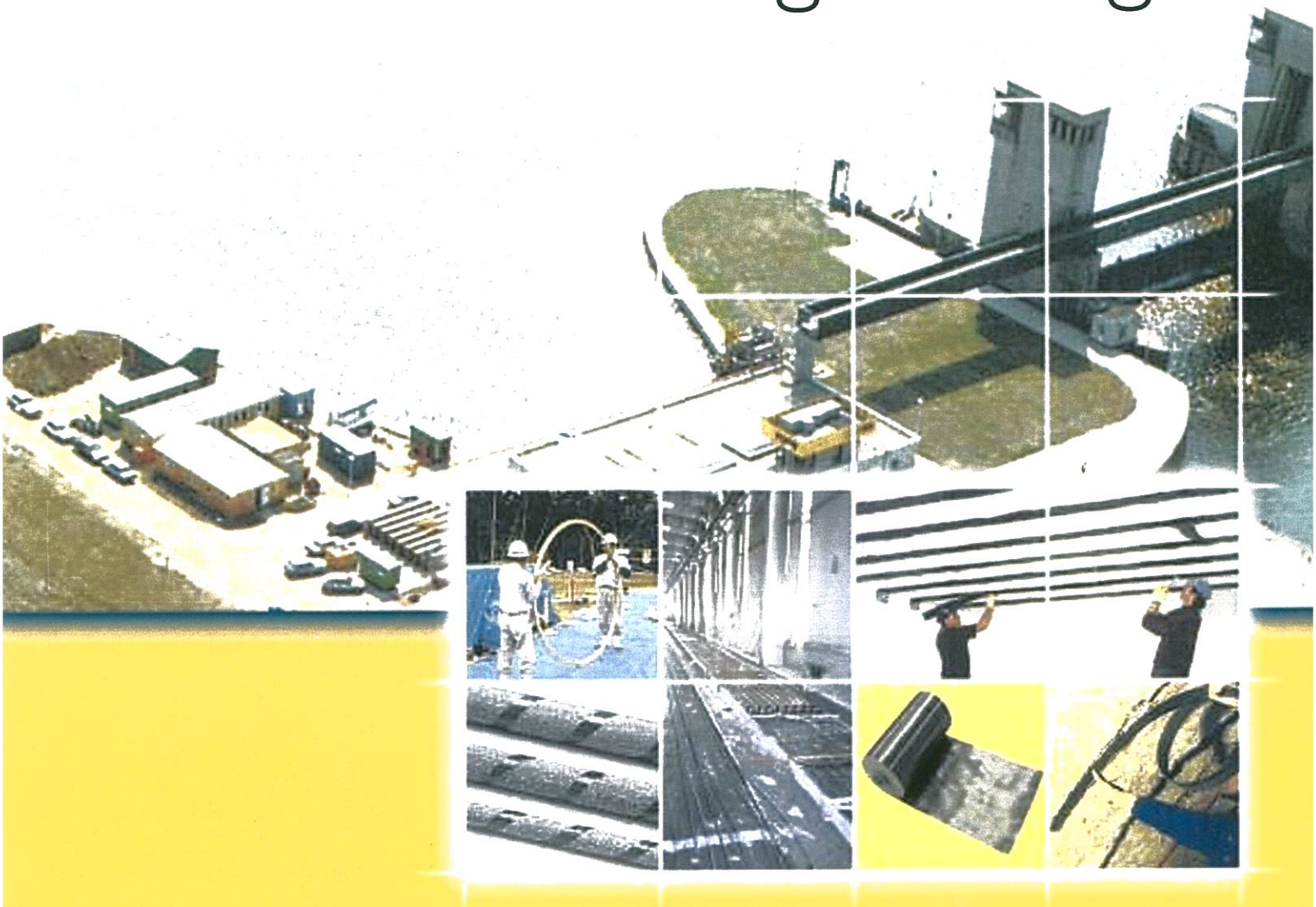
Civil Engineering

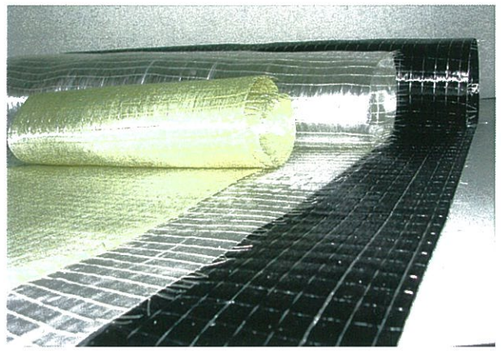


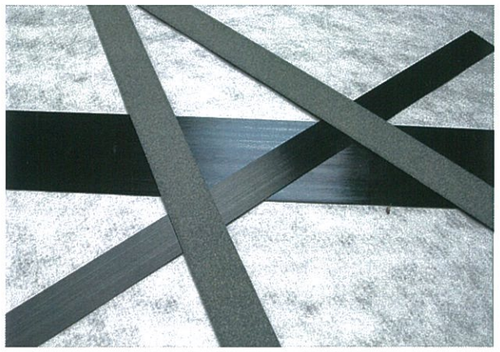
sireg

Product line for structural reinforcement

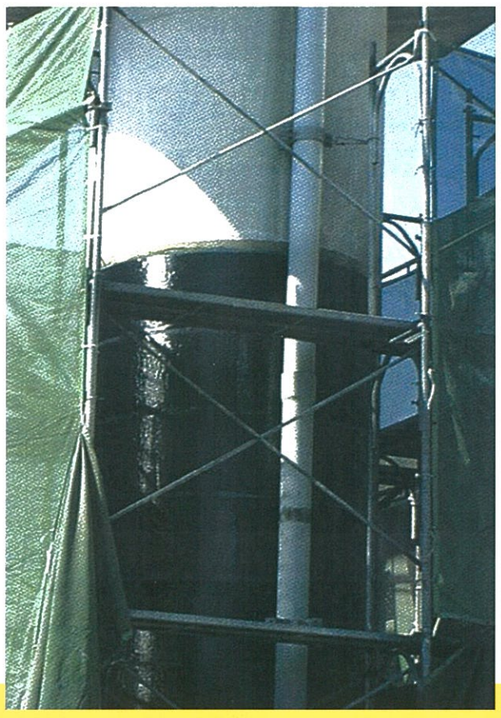
CARBOPREE® - GLASSPREE® - ARAPREE®

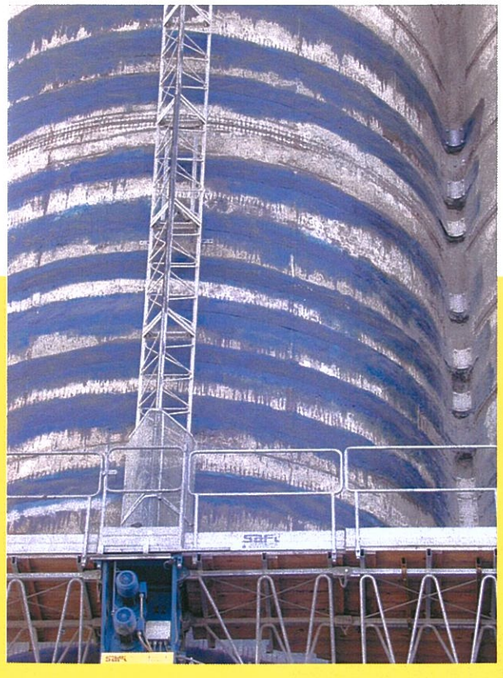
The use of composite materials to reinforce and repair existing structures dates back to more than 20 years ago.
These composite materials are commonly called FRP (Fiber Reinforced Polymers).
FRP systems are used in all those structures (concrete, wood, steel ...) that need to be reinforced as a consequence of deterioration, errors in design or construction, change in use, seismic retrofitting, increase in service or in ultimate load.
Three classes of products are commonly applied: fabrics, laminates and bars.





The FRP work strengthening structures in tension, therefore they can be applied either in the lower part of beams or slabs in order to increase their flexural strength or on the sides of the beams in order to increase their shear strength. In addition, they can be wrapped around columns or piles to provide confinement and to enhance load capacity and ductility, which is the main and fundamental problem in seismic retrofitting.
They can be employed to reinforce concrete or masonry walls to increase their seismic resistance and to better stand wind loads and also as an external lining for concrete tubes, silos or tanks in order for them to achieve a higher internal pressure.





In those cases where FRP materials can be useful, it is necessary to recognize that there are reasonable limits to the additional strengthening they can provide to the structure. Typically an increase of 50% in the performance of the structure is considered within these limits.
Applications where FRP systems may not be useful include: correction of punching shear problems in beams or footings, correction of vibration problems, increase in compression strength where confinement is not possible.
FRP products may also be used in new structures: concrete wall without any metallic reinforcement, structures exposed to high corrosion.

Advantages offered by FRP materials

- durability
- lightweight
- fast and easy installation
- possibility of installation in areas of limited access
- no alteration of the appearance of the reinforced structure
- possibility to apply the product on surfaces having complex geometry

Main benefits of using FRP materials

- reduction of the deflection (increase in stiffness of the structure)
- limitation and control of the cracking phenomenon (increase in the durability of the structure)
- increase in the load capacity of the structure
- increase in ultimate load / failure load (increase in safety of the structure)

To be able to obtain one or more of the above mentioned benefits, the engineer will have to choose among different parameters concerning the reinforcement to be applied on the structure:

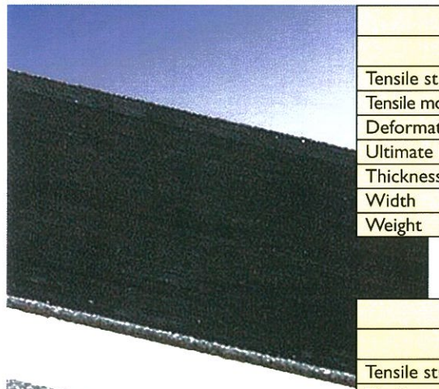
- FRP types (fabrics, laminates, bars)
- material type (carbon fiber, aramid fiber, glass fiber)
- length, thickness and orientation of the reinforcement
- adhesive type

The combination of these parameters is a very important key factor for the project.
For example, the reduction of mid-span deflection under load at service of a beam or slab can be achieved using different types of FRP (fabrics, sheets or bars), also through a combination of their different lengths or thicknesses.
Once the most appropriate material has been chosen and its main mechanical features (tensile strength, elastic modulus and deformation) have been considered, the main data of the structure that has to be reinforced have to be evaluated, such as: dimensions of the beam or slab, concrete compressive strength, number and type of reinforcing bars inside the structure, live load and dead load.
For this reason, the evaluation of all these data is quite complex. Thanks to its long experience in the manufacturing of FRP materials, Sireg offers technical assistance to its customers from the early stage of the project, indicating the most adequate reinforcing material to be used. This can be done on the basis of the above mentioned parameters and according to the kind of improvement required by the structure, such as: increase in the service load, increase in the ultimate load, enhancement of the ductility etc.
Sireg designs the reinforcement with FRP materials taking into account the international codes and guidelines (for example the A.C.I. 440) for the use of composite materials as reinforcement in RC structures.

TYPE OF REINFORCEMENT

External structural reinforcement
Flexural strengthening of beams or slabs with Carbopree® carbon fiber plates

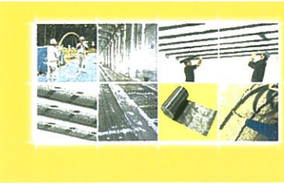
Carbopree® carbon fiber plates are a family of laminates used as external reinforcement.
Divided into **HS** High Strength plates and **HM** High Modulus plates, they are manufactured in different sizes which can vary between 50 mm and 120 mm width and between 1.2 mm and 1.4 mm thickness.
This way, the engineers can count on a wide range of products which will offer them the possibility to choose the most appropriate one according to the project requirements.
The particularity of the Carbopree® plates is to have a smooth side (side to be bonded onto the structure) and a side covered with quartz sand in order to offer a better adhesion to the finishing materials or fire resistant materials which are applied to the plate.
The plates are supplied in rolls of 50 or 100 m length in order to be easily shipped to the jobsite where they can be cut at the desired length.
Carbopree® plates are applied on the positive bending moment area of the structure by means of an epoxy paste and can be considered an excellent alternative to the application of carbon fiber fabrics since their application is easier and quicker and can guarantee a better result.



CARBOPREE® PLATE HS				
	50 x 1.2	**80 x 1.2**	**100 x 1.2**	**120 x 1.2**
Tensile strength ASTM D3039	2800 MPa	2800 MPa	2800 MPa	2800 MPa
Tensile modulus of elasticity ASTM D3039	165 GPa	165 GPa	165 GPa	165 GPa
Deformation ASTM D3039	1.8%	1.8%	1.8%	1.8%
Ultimate load ASTM D3039	168 kN	268 kN	335 kN	403 kN
Thickness	1.2 mm	1.2 mm	1.2 mm	1.2 mm
Width	50 mm	80 mm	100 mm	120 mm
Weight	125 gr/m	185 gr/m	238 gr/m	280 gr/m

CARBOPREE® PLATE HS					
	50 x 1.4	**60 x 1.4**	**90 x 1.4**	**100 x 1.4**	**120 x 1.4**
Tensile strength ASTM D3039	2800 MPa	2800 MPa	2800 MPa	2800 MPa	2800 MPa
Tensile modulus of elasticity ASTM D3039	165 GPa	165 GPa	165 GPa	165 GPa	165 GPa
Deformation ASTM D3039	1.8%	1.8%	1.8%	1.8%	1.8%
Ultimate load ASTM D3039	196 kN	235 kN	352 kN	392 kN	470 kN
Thickness	1.4 mm	1.4 mm	1.4 mm	1.4 mm	1.4 mm
Width	50 mm	60 mm	90 mm	100 mm	120 mm
Weight	135 gr/m	165 gr/m	236 gr/m	262 gr/m	315 gr/m

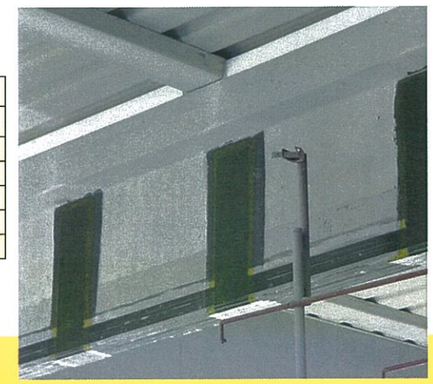
CARBOPREE® PLATE HM				
	50 x 1.2	**80 x 1.2**	**50 x 1.4**	**60 x 1.4**
Tensile strength ASTM D3039	2300 MPa	2300 MPa	2300 MPa	2300 MPa
Tensile modulus of elasticity ASTM D3039	200 GPa	200 GPa	200 GPa	200 GPa
Deformation ASTM D3039	1.4%	1.4%	1.4%	1.4%
Ultimate load ASTM D3039	138 kN	220 kN	161 kN	193 kN
Thickness	1.2 mm	1.2 mm	1.4 mm	1.4 mm
Width	50 mm	80 mm	50 mm	60 mm
Weight	116 gr/m	220 gr/m	135 gr/m	165 gr/m

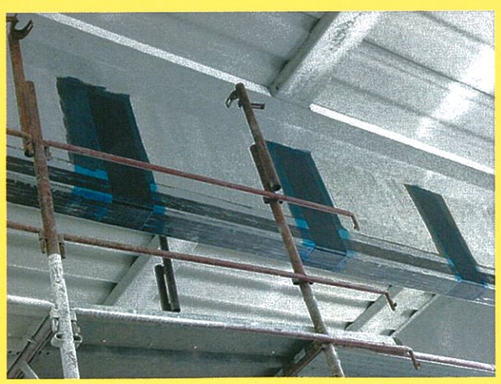


Shear and flexural strengthening of beams with Carbopree® carbon fiber sheets

The most effective method for shear strengthening using FRP sheets is to wrap the whole section of the beam. Unfortunately, this method is often hardly applicable on jobsite from a feasibility point of view. The presence of monolithic beams or of other supporting elements often precludes the possibility to apply the fabric also around the upper part of the beam section. Therefore, the most common method is to wrap both sides and the lower part of the section.
This method, called "U wrapping", is feasible and quite effective to increase the shear moment of the section. It is important to stress out that when the fabric is applied U shaped on a beam, its extremities should be anchored to the beam itself by means of a composite material bar (carbon fiber or glass fiber). This rod can be inserted together with the fabric inside a groove previously carried out along the whole length of the beam and filled with epoxy paste, so that, once the bar is inserted, the fabric is anchored.
In this way, the peeling phenomena (detachment of the fabric from the structure) can be prevented.
The same concept can be applied if the composite bars are replaced by L shaped steel profiles (although this second method is more expensive, slower and more difficult to be carried out, if compared to the application of the composite bars). One side of the L profile is screwed to the upper part of the beam, while the other side is bonded to the fabric by means of epoxy resin.
Finally, depending on the project requirements, the fabric can be applied in a continuous way on the beam or in stripes evenly spaced and distributed along the whole beam length.
This latter application allows a better dispersion of the humidity present in the concrete and a better optimization of the quantity of material to be used.

CARBOPREE® SHEET HS		
	HS 300	**HS 600**
Tensile strength average ASTM D3039	3000 MPa	3000 MPa
Tensile modulus of elasticity ASTM D3039	230 GPa	230 GPa
Deformation ASTM D3039	1.5%	1.5%
Thickness of dry tissue	0.165 mm	0.330 mm
Weight	300 gr/m²	600 gr/m²





Ductility enhancement / shear and flexural

strengthening of columns (column wrapping) with Carbopree®, Arapree® and Glasspree® sheets

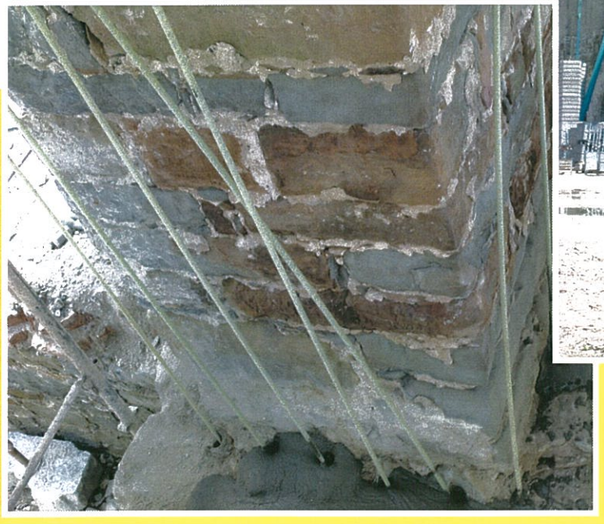
The use of FRP fabrics - Carbopree®, Arapree® and Glasspree® sheets - to increase and to improve the axial compression behavior of RC columns has a major effect if compared to the reinforcement carried out with steel stirrups, due to the fact that the fabrics offers a continuous confinement along the whole column length.
The use of FRP fabrics to increase shear moment and load capacity as well as ductility of the columns is very effective and proven.
The application of the fabric is carried out wrapping the column in a continuous way transversely, from the base until the section under the slab or beam.
When the columns are subject both to axial and to flexural loads, the use of vertical bars or laminates is recommended.
It is important to notice that the most important problem (creep) which affects glass fiber sheets is not a concern when they are used for this kind of application because under permanent load the confinement of the column is stress-free for FRP products.
Finally, it is interesting to note that the low tensile strength and low elastic modulus of both glass fiber sheets and aramid fiber sheets – if compared to the values of carbon fiber sheets - offer a bigger ductility to the column, allowing a bigger tolerance to the deformations especially in the event of an earthquake.
Sireg manufactures a great variety of composite sheets having different technical features and different grammages in order to offer the engineers the possibility to design the project optimizing the application of the material type basing on the real technical needs.
For example, Carbopree® sheets can be manufactured in different grammages: 300 gr/m² or 600 gr/m² in high strength unidirectional configuration, Arapree® sheets can be manufactured in 300 gr/m² or 400 gr/m² while Glasspree® sheets can be manufactured in 600 gr/m² up to 950 gr/m².

GLASSPREE® SHEET		
	600	**900**
Tensile strength average ASTM D3039	1700 MPa	1700 MPa
Tensile modulus of elasticity ASTM D3039	65 GPa	65 GPa
Deformation ASTM D3039	2.6%	2.6%
Thickness of dry tissue	0.23 mm	0.35 mm
Weight	600 gr/m2	900 gr/m2

INTERNAL STRUCTURAL REINFORCEMENT

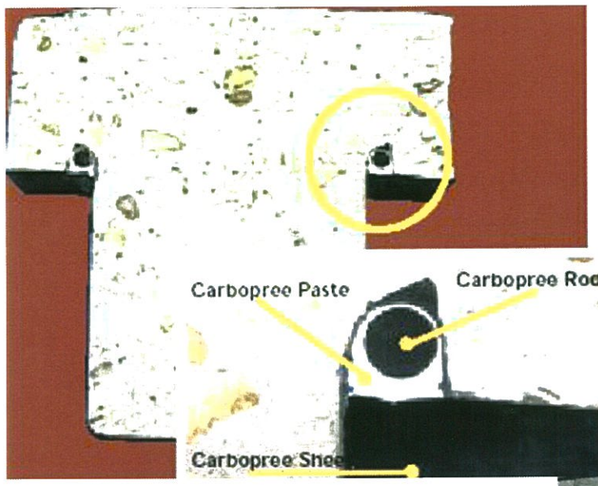
Shear and flexural strengthening of concrete structures with N.S.M. (Near Surface Mounted) technique carried out with Carbopree®, Arapree® and Glasspree® glass fiber bars

If compared to steel bars, Carbopree®, Arapree® and Glasspree® rods offer an excellent resistance to corrosion, an excellent tensile strength, a good fatigue resistance as well as a very light weight.
The application of these bars ranges from seismic reinforcement of masonry walls and columns to flexural strengthening of RC slabs and beams.
In particular, Carbopree® carbon fiber bars are suitable to be used with a technique called N.S.M. (Near Surface Mounted).



Basically, a longitudinal groove is executed along the whole length of the beam or slab to be reinforced, then the groove is filled with an epoxy paste and afterwards the bar is introduced into it in order to force the epoxy paste to cover the bar completely. The bar is finally sealed inside the groove by means of a finishing epoxy resin or mortar.

One of the advantages of the N.S.M. technology, if compared to the application of carbon fiber laminates or sheets, is the possibility to anchor the bars into a structure which is adjacent to the reinforced one. Furthermore, the installation is much faster.



ARAPREE® ROD				
	ø 5.5 mm	ø 7.5 mm	ø 10 mm	ø 12 mm
Tensile strength ASTM D3039	1400 MPa	1400 MPa	1400 MPa	1400 MPa
Tensile modulus of elasticity ASTM D3039	60 GPa	60 GPa	60 GPa	60 GPa
Deformation ASTM D3039	2.3%	2.3%	2.3%	2.3%
Section	23 mm2	44 mm2	78 mm2	114 mm2
Ultimate load ASTM D3039	32 kN	65 kN	109 kN	150 kN
Linear weight	29 gr/m	57 gr/m	102 gr/m	145 gr/m

GLASSPREE® ROD										
	ø 6 mm	ø 8 mm	ø 10 mm	ø 12 mm	ø 16 mm	ø 20 mm	ø 22 mm	ø 25 mm	ø 28 mm	ø 32 mm
Tensile strength ASTM D3039	1000 Mpa	1000 MPa	1000 MPa	1000 MPa	1000 MPa	900 MPa	900 MPa	900 MPa	900 MPa	850 MPa
Tensile modulus of elasticity ASTM D3039	40 GPa	40 GPa	40 GPa	40 GPa	40 GPa	40 GPa	40 GPa	40 GPa	40 GPa	40 GPa
Deformation ASTM D3039	2.8%	2.8%	2.8%	2.8%	2.8%	2.8%	2.8%	2.8%	2.8%	2.8%
Section	28 mm2	50 mm2	78 mm2	113 mm2	200 mm2	314 mm2	379 mm2	490 mm2	615 mm2	803 mm2
Ultimate load ASTM D3039	28 kN	50 kN	78 kN	113 kN	200 kN	282 kN	340 kN	440 kN	550 kN	680 kN
Linear weight	55 gr/m	98 gr/m	155 gr/m	220 gr/m	340 gr/m	640 gr/m	770 gr/m	980 gr/m	1200 gr/m	1540 gr/m

This technology becomes particularly attractive also because it allows flexural strengthening of the negative zones both in slabs and beams. Here an external reinforcement would need a layer of material to avoid any mechanical and / or environmental damage which would interfere with already existing structures such as: columns, floors or walls.
Carbopree®, Arapree® and Glasspree® rods are manufactured in diameters ranging from 3 mm up to 40 mm in several configurations.

CARBOPREE® ROD HS						
	ø 3 mm	ø 5.5 mm	ø 7.5 mm	ø 10 mm	ø 12.5 mm	ø 16 mm
Tensile strength ASTM D3039	2300 MPa	2300 MPa	2300 MPa	2300 MPa	2300 MPa	2300 MPa
Tensile modulus of elasticity ASTM D3039	130 GPa	130 GPa	130 GPa	130 GPa	130 GPa	130 GPa
Deformation ASTM D3039	1.8%	1.8%	1.8%	1.8%	1.8%	1.8%
Section	7 mm2	23 mm2	44 mm2	78 mm2	122 mm2	200 mm2
Ultimate load ASTM D3039	16 kN	54 kN	101 kN	180 kN	280 kN	460 kN
Linear weight	12 gr/m	40 gr/m	75 gr/m	130 gr/m	195 gr/m	340 gr/m

CARBOPREE® ROD HM		
	ø 5 mm	ø 7.5 mm
Tensile strength ASTM D3039	2300 MPa	2300 MPa
Tensile modulus of elasticity ASTM D3039	200 GPa	200 GPa
Deformation ASTM D3039	1.4%	1.4%
Section	19 mm2	44 mm2
Ultimate load ASTM D3039	45 kN	101 kN
Linear weight	40 gr/m	72 gr/m

OTHER APPLICATIONS WITH FRP MATERIALS

Strengthening of structures built near the seaside

One of the most important problems concerning the structures built near the sea is the corrosion of the reinforcing steel which deteriorates very quickly if not properly treated or protected before being placed inside the concrete structure. Unfortunately, steel protection is very expensive and cannot always guarantee a long durability whereas composite materials are not affected either by salted water or by marine environment.
Some examples of possible applications using composite materials are: retaining walls, piers, floating structures, concrete flooring.

Strengthening of concrete structures and floors treated with antifreeze salts

The use of FRP bars allows to eliminate the problem of corrosion of reinforcing bars in all those cases where de-icing salts are used, for instance on roads, bridges or concrete floors that are subject to icing during the winter season.
The problem deriving from the use of de-icing salts is that the substances contained therein (usually sodium or magnesium hydrochloride) penetrate into the concrete pores reaching the steel reinforcement. This latter, once in contact with these substances, starts a very fast process of corrosion which makes in turn the structures very expensive to maintain.
For this reason, many countries where frequently the roads freeze during the winter season have replaced the traditional framework with the glass fiber reinforcement which is totally insensitive to the substances listed above.
This solution permits to contain much of the maintenance costs and to extend the life of the reinforced structures.
Some examples of applications are: slabs of bridges, roads, concrete safety barriers (Jersey), parking lots, retaining walls and foundations.

Reinforcement in the presence of magnetic fields and stray currents

There are some special cases where it is necessary to reinforce the structures with non-conductive materials or with materials transparent to the magnetic fields, for instance:
airport control towers, places where MRI equipments are positioned in hospitals, support structures for electrical towers, radar support structures, floors where the turbines are paved in hydroelectric plants.
In all these cases, the use of a ferrous support material will not only jeopardize the operation of the structure and of its equipments, but it will also risk to erode them rapidly due to the galvanic corrosion induced by electricity.
Therefore, the only cost-effective and structurally safe alternative is to replace the traditional iron framework with another one made of composite material such as fiberglass bars Glasspree® or aramid fiber Arapree® which, besides being transparent and insensitive to electromagnetic fields, are not conductive and can provide the necessary structural reinforcement to these buildings.